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FLIGHT TERMINATION SYSTEM
BATTERY GUIDELINES

OCTOBER 1989

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October 1989

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Range Safety Group
Range Commanders Council
White Sands Missile Range, NM 88002

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This document is intended to be used as a guide for range users requiring a flight termination battery. Provides the user with guidelines for incorporating technical and safety criteria necessary to describe a power source (battery) which will be compatible with the mission critical needs of a flight termination system (FTS).

Flight termination; battery; FTS

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**FLIGHT TERMINATION SYSTEM
BATTERY GUIDELINES**

OCTOBER 1989

**Prepared by
Flight Termination System Committee
Range Safety Group
Range Commanders Council**

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Flight Termination System Battery Guidelines

INTRODUCTION

This document is intended to be used as a guide for range users requiring a flight termination battery. It will provide the user with guidelines for incorporating technical and safety criteria necessary to describe a power source (battery) which will be compatible with the mission critical needs of a flight termination system (FTS).

All batteries used to provide the electrical power for an FTS shall have a proven performance reliability of .999 at the 95 percent confidence level. Performance reliability shall be established through statistically based testing. The battery specification, as a minimum, shall include all of the applicable operational, mechanical, electrical, and environmental characteristics of the FTS. As a final product, any battery to be used with an FTS shall be from those units for which lot-acceptance data is in compliance with the specification and the data evaluation requirements of this document. A quality assurance program, such as MIL-Q-9858, must be invoked in the purchase document and placed in operation concurrent with the qualification program so as to allow its assessment prior to beginning production.

Scope

Included are references, definitions, operating and nonoperating requirements and testing, and special considerations such as safety, quality assurance, reliability, shipping, and handling.

The requirements, tests, and special considerations outlined in this document are minimal and will require further detail prior to incorporation into a specification or acquisition document. These requirements will not ensure acceptable operating requirements or safe use of batteries. Guidance is required by each individual Range Safety Office.

Definitions

As a power source, batteries are usually classified as primary, secondary, or reserve.

Primary Battery. A battery not intended to be recharged and is disposed of in controlled conditions when the battery has delivered all its electrical energy.

Secondary Battery. A battery which, after discharge, may be restored by the passage of electrical current in the opposite direction to that of discharge.

Reserve Battery. A battery which may be stored in an inactive state and made ready for use by adding electrolyte, or in the case of a thermal battery, melting solidified electrolyte.

References

Linden, D., Handbook of Batteries and Fuel Cells New York: McGraw Hill, 1984 (ISBN 0-07-037874-6).

BATTERY CHARACTERISTICS

Battery characteristics include electrical performance, output, operating life, and activation.

Electrical Performance

With the battery mounted by its normal means, the performance characteristics shall be met under any combination or all of the environmental conditions specified and in any orientation specified.

Output

The output voltage shall be available at the appropriate terminals for the time specified. The voltages shall be within the specified range when connected to the specified electrical load for any of the operating environments or for any combination.

Activation

Battery activation is defined as the process of making a reserve cell function, which can be done by introducing an electrolyte, by electrical initiation of an igniter, or by other means. For those batteries activated by application of an external electrical current, the minimum voltage, current, and applied duration shall be at least 10 percent greater than the activator manufacturer's all-fire rating.

All secondary batteries intended for specification compliance or which will be placed into operational service shall be subjected to the manufacturer's recommended charging and maintenance procedures. Alternatively, charging and maintenance procedures can be specified by an activity when authorized by the Range Commander. The same activity will certify that the battery has been maintained, installed correctly, and satisfactorily tested prior to flight. A log of all battery cycles including charging and discharging shall be kept for each battery by battery serial number.

Operating Life

When connected to the specified electrical load, the operating life shall be at least 150 percent of the calculated mission profile operating time with adequate energy to activate the FTS a second time or as approved by the Range Commander. The mission profile should include all discharge time from activation, test, launch, and flight.

An area of safety concern is the hangfire or misfire condition. During these scenarios, it is possible in some systems for the launch platform to impress a charge voltage on the output of the battery causing a violent reaction such as venting or rapid disassociation of the battery.

BATTERY TYPES AND USES

Batteries can be classified as primary, secondary, and reserve. No one type will provide optimum performance for all situations. Type selection for use with an FTS will depend on space available, weight restrictions, operating temperatures, and environments along with special circumstances such as safety, availability, and economics. Because performance varies with battery types, the type should be the leading consideration. In all cases, there should be no compromise affecting reliability. Reliability can be achieved through a comprehensive quality assurance program which requires close monitoring by competent personnel. Suggestions for battery type selection can be found in appendix A.

Flight termination systems most often require an operating voltage of 24 to 36 volts. Other operating voltages such as 5 volts may become more common as the use of integrated circuitry becomes more prevalent. Battery size is determined by its chemical type and by the amount of power required for a given time. Energy density and specific energy for some secondary systems are shown in figures 1 and 2. It is very important to know the operating temperature because it affects the amount of energy available, operating life, shelf life, and rise time for the battery.

Primary Batteries

Selection of this type of FTS power should be for those systems which require the greatest energy density. Present technology suggests the use of either lithium sulfur dioxide (Li/SO_2) or lithium thionyl chloride (Li/SOCl_2). The use of either type requires prior approval from the user agency. A definite advantage for these units is that they can be tested prior to, or while in use, and are capable of operating over a wide temperature range of -40 to $+50$ °C with energy derating between -40 and 20 °C. However, at higher storage temperatures, passivation within the battery can delay output.

Before discussing your requirements with a manufacturer and in lieu of having the services of dedicated battery personnel, an approximation of battery sizing can be obtained using the following steps:

1. Multiply your operating current (amperes) by the operating time (hours) to obtain ampere-hours; the term by which most primary cells are rated.

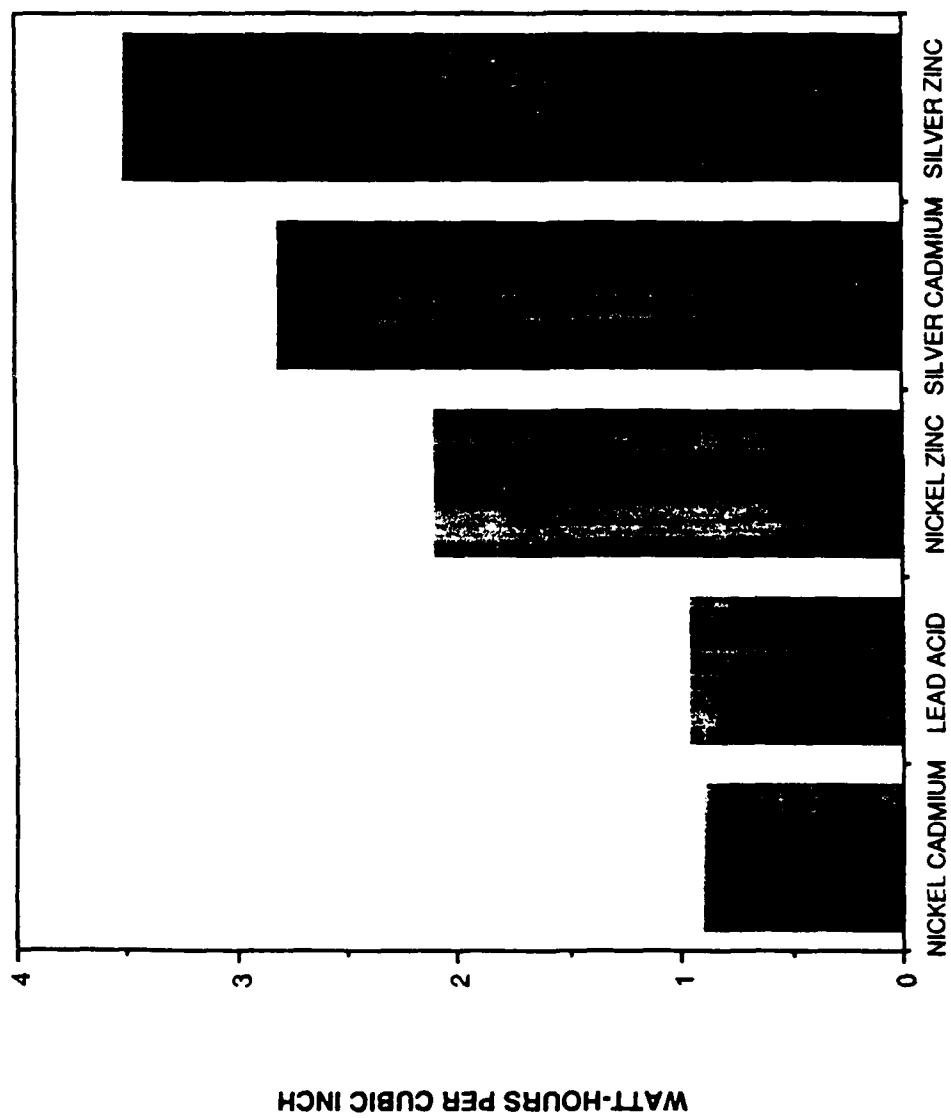


Figure 1 COMPARISON OF ENERGY/UNIT - VOLUME OUTPUT
FOR RECHARGEABLE BATTERY SYSTEMS

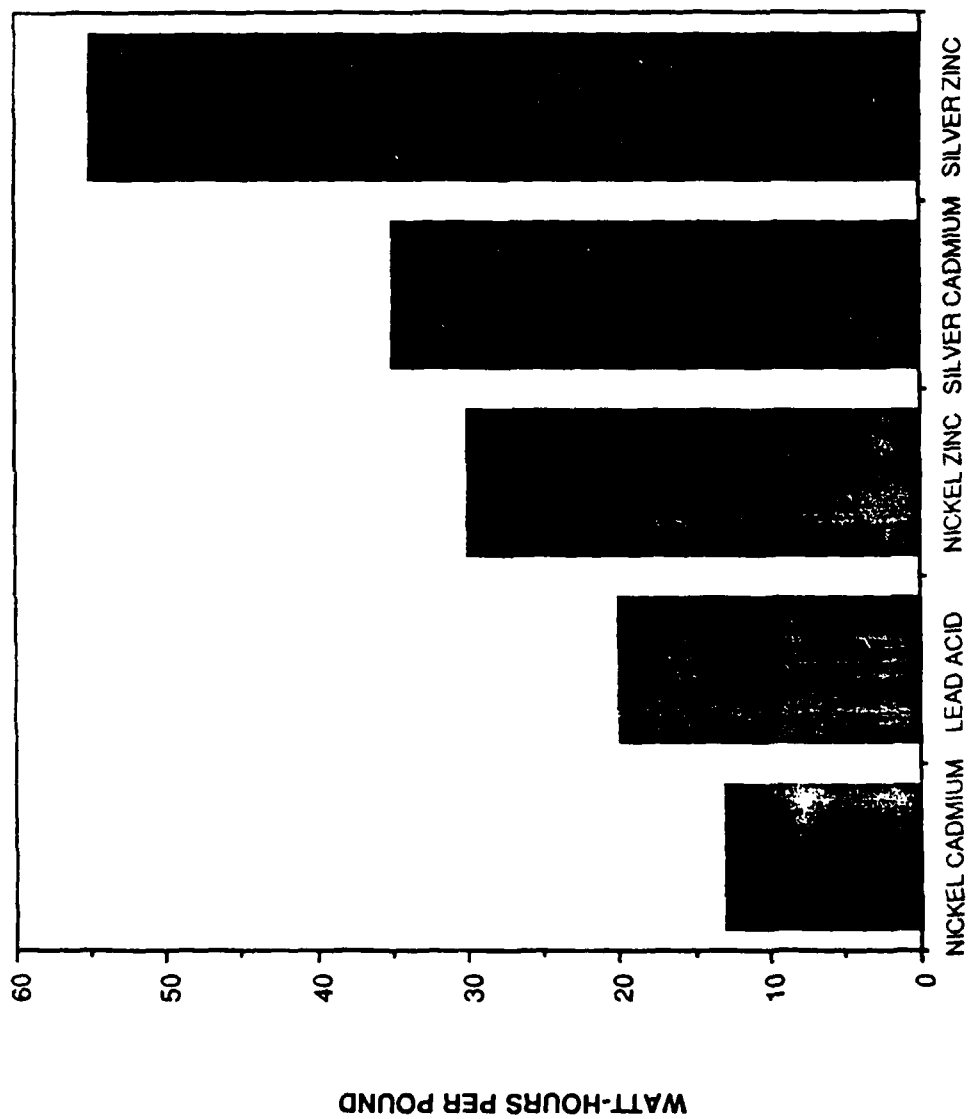


Figure 2 **COMPARISON OF ENERGY/UNIT - WEIGHT OUTPUT
FOR RECHARGEABLE BATTERY SYSTEMS**

a. If the operating current is not constant but has high and low values for various time periods, it will be necessary to calculate these energy levels separately and sum them to get the true ampere hour value.

b. When current levels have peak values above two to three times the average operating current, no matter the duration, it may be necessary to increase the cell ampere hour capacity or cell characteristics to keep the output voltage above the minimum specified.

2. Determine the specified operating voltage and the number of cells necessary to obtain that voltage.

a. Additionally, series diodes to prevent charging and other fuses/safety devices should be added to each series string to ensure that all voltage drops are taken into consideration.

b. For sulfur dioxide batteries that are to be used over typical military temperatures, use a value of 2.65 volts per cell with an energy density of approximately 280 Wh/kg.

c. For thionyl chloride batteries, use 3.3 volts per cell with an energy density of 300 Wh/kg. These are only rough values.

3. Divide the required voltage by the individual cell voltage for the type of lithium battery being considered. Any fractional number shall be raised to the next whole number.

Having determined the cell capacity and the number required, a review of manufacturer's data sheets should give a reasonable approximation of form and fit.

When lithium active cells or batteries are to be purchased, the purchase order should specify balanced cells. Balanced cells have chemically matched amounts of anode and cathode material which result in a basically inert cell or battery at depletion. This type of cell provides an additional measure of safety in a design application.

Secondary Batteries

In this class of rechargeable batteries, some have very good power and energy densities for use with FTS and can accommodate preflight voltage level testing. They are somewhat sensitive to military operating temperature and require charging to keep them in a state of readiness. The principal chemistries compatible with FTS requirements are sealed nickel cadmium, lead acid, and silver zinc. When use at very low temperatures is considered, an electric heater blanket may be employed if an external power source is available. It is recommended that only dedicated charging systems be used for secondary batteries that power an FTS. In this case, the charging system becomes a factor in battery reliability.

Nickel Cadmium. Nickel cadmium batteries are mechanically rugged and long lived. This type of battery provides reliable high rate discharge service in applications where large peaks of power, fast

recharging, or many cycles are required without excessive size and weight. The cost, however, is higher than that of lead acid batteries. Depending on the electrical load and cell temperature at discharge, the voltage will be about 1.26 at the beginning of discharge for a fully-charged cell. For new applications with FTS, the sizing information for primary cells applies. Capacity is dependent upon cell size, cell design, and other battery characteristics. The average discharge voltage is dependent upon the size and construction of the cell, the rate of discharge, the cell temperature of the application, and the previous history of the cell in cycling or idleness.

Lead Acid. When comparing lead acid batteries with nickel cadmium batteries, there is a weight and size increase with lead acid batteries; however, the operating life and pulse capabilities are usually greater. The nominal voltage at room ambient is about 2.0 volts per cell with energy densities of about 25 Wh/kg. Low temperature conditions will result in lower battery capacity. For new applications to power an FTS, use the sizing guidelines for primary cells and the suggested nominal voltage. Most lead acid cells now in use for military applications are of the sealed gel cell type which does not require any maintenance other than charging after use. There is normally no memory problem with these cells/batteries.

Silver Zinc. Rechargeable silver zinc batteries can provide higher current, more level voltage, and up to six times greater watt-hour capacity per unit weight and volume than lead acid and nickel cadmium storage batteries. Because rechargeable silver zinc batteries are capable of delivering high watt-hour capacities at discharge rates less than 30 minutes, they are used extensively for missile and torpedo applications. Such batteries are highly efficient and mechanically rugged, operate over a wide temperature range, and offer good shelf life. They can be manufactured to provide both high-rate or low-rate discharge energy profiles. Nonetheless, there are a number of problems which are somewhat unique to this type of battery. For example, the number of recharge cycles is lower than most secondary batteries, and the battery voltage under discharge conditions has a distinct plateau which is rate dependent. Low temperature performance is similar to other secondary batteries and offers no advantage over other chemistries. These rechargeable batteries must be totally discharged before they can be charged to full capacity.

Reserve Batteries

Reserve batteries include silver zinc and thermal varieties as well as those composed of alkalines or lithium manganese dioxides.

Silver Zinc. Activation of silver zinc units is usually done by applying an electric current for as long as 50 milliseconds to the igniter of a gas generator, which applies pressure within less than one second to force electrolyte into the battery cells and provide battery activation. The nominal cell voltage is 1.5 volts per cell. This battery type is temperature sensitive below 10 °C without preheating of the electrolyte. The storage life of unactivated units in an uncontrolled environment is limited to five years.

Thermal. A thermal battery has a solid electrolyte which is melted by an internal pyrotechnic heat source train. The heat source is ignited by an electrical current applied to an igniter bridge wire or a mechanically actuated percussion-type primer. Lithium type thermal batteries offer the best energy densities. They have a very wide operating temperature range suited to almost all military situations and environments. They can be designed for an operating life from seconds to over 30 minutes. Their storage life is known to be over 15 years. The case temperature, which can reach in excess of 400 °C, must be considered for proximity to temperature sensitive electronic components when mounting a thermal battery. The battery operating temperature must also be taken into consideration before mounting near ordnance components. Lithium systems have cell voltages of approximately 1.8 volts per cell with energy densities upwards of 130 Wh/kg.

Other. Other batteries whose chemical systems are composed of alkalines or lithium manganese dioxides are available. However, because of their package size they are not able to deliver the same power and energy levels as the more active lithium systems, and thus are not considered here for operating the typical FTS.

TESTING

All tests must be fully documented. At the completion of a specific test and before performance of another test, the battery shall be subjected to visual, mechanical, and nondestructive (nonoperating) electrical tests which will verify that no damage has occurred. When the test requires a measurement, the value shall be recorded. Anomalies should be resolved prior to test continuation.

Qualification Tests

A qualification test program will be implemented to verify that a battery manufacturer is capable of producing a unit which will fully comply with the FTS battery specification. The examinations or tests shown in table 1 shall be conducted on the number of units whose singular lot integrity is representative of the manufacturer's construction methods and processes. The number of batteries required for qualification shall be determined by the amount of individual and composite tests that will indicate specification compliance. Table 1 outlines the qualification tests that may be required for primary and secondary batteries. These tests are, of course, dependent on the particular chemistry of the battery and its unique application.

Nonoperational Tests

For qualification tests, evaluation of measurements is confined to being within specification limits. When anomalies are present, determining the cause is imperative to the qualification effort. A comprehensive failure analysis with verified follow-up corrective action is required following any functional failure during qualification tests. This same philosophy applies for any failure during

TABLE I. QUALIFICATION TESTS

<u>Type of Examination or Test</u>	<u>Primary</u>	<u>Secondary</u>
Visual and mechanical	Y	Y
Workmanship	Y	Y
Markings	Y	Y
Overall dimensions	Y	Y
Weight	Y	Y
Seal	Y	Possibly
Radiographic inspection	Y	N
ELECTRICAL		
Igniter Circuit Resistance	Y	N
Igniter Circuit No-Fire Current	Y	N
Polarity	Y	N
Dielectric withstanding voltage	Y	N
Insulation resistance	Y	N
Open circuit voltage	Y	N
Heater circuit resistance	N	Ag-Zn
Heater circuit operation	N	Ag-Zn
ENVIRONMENTAL (nonoperating)		
Low temperature exposure	Y	Y
High temperature exposure	Y	Y
Thermal shock	Y	Y
Mechanical shock at low temperature	Y	Y
Mechanical shock at high temperature	Y	Y
Pyrotechnic shock at low temperature	Y	Y
Pyrotechnic shock at high temperature	Y	Y
Acceleration of low temperature	Y	Y
Acceleration of high temperature	Y	Y
Random vibration at low temperature	Y	Y
Random vibration at high temperature	Y	Y
Altitude	Y	Y
Other pertinent flight environments	Y	Y
ENVIRONMENTAL (operating)		
Low temperature	Y	Y
High temperature	Y	Y
Pyrotechnic shock at low temperature	Y	Y
Pyrotechnic shock at high temperature	Y	Y
Random vibration at low temperature	Y	Y
Random vibration at high temperature	Y	Y
Altitude	Y	Y
NAVSEANOTICE 9310 Safety testing	Y	N

lot-acceptance testing. For lot-acceptance tests, the evaluation of measurements, in addition to meeting specified values, should be reviewed for lot-to-lot variations.

Operational Tests

For qualification tests, the values obtained for the electrical parameters must meet specification parameters. Mechanical properties such as post-test dimensions, will depend on the battery type, test temperature, and the test vehicle mount. For lot-acceptance tests, the electrical value ranges should begin to establish a recognizable pattern. Evaluating the range of data-point values at critical performance events will provide evidence of the manufacturer's quality controls. The allowable variations, within specification, should be a parameter requisite. When a lot-acceptance test battery fails to meet any specified parameter during discharge, a failure review must be conducted to determine disposition of the lot. It is recommended that consideration be given to performing comprehensive failure analysis on a failed battery. If the analysis indicates that the failure is classified as a nonrelevant failure resulting from external causes, consideration can be given to accepting the lot. If the cause of the failure is attributed to a manufacturing flaw, the lot should be rejected. If the failure is related to a manufacturing problem with the specific failed battery (identified by radiographic inspection or other analysis), the lot may be reformed and an additional group of batteries subjected to the lot-tests process. Rework of the affected lot should not be permitted. A reworked lot can adversely affect reliability.

MARKING

Individual battery markings are usually part of the battery outline drawing. For FTS use, battery markings shall provide traceability to the manufacturer's lot.

PACKAGING AND SHIPPING

For packaging and shipping batteries, follow Federal Standards and the manufacturer's recommendations.

HANDLING AND STORING

The type of battery and its unique chemistry will determine both short and long term storage criteria and the type of facilities required. Department of Defense directives affecting safety are enforced by each government agency such as the Air Force, Army, and Navy to provide required storing and handling conditions. Care

should be taken to ensure proper storage conditions especially for lithium batteries. For long shelf-life batteries, surveillance testing is considered appropriate to ascertain if any degradation has taken place.

APPENDIX A
FTS BATTERY SAFETY MATRIX

FTS BATTERY SAFETY MATRIX

SAFETY CONSIDERATIONS

<u>Type of Battery</u>	<u>Leakage</u>	<u>Venting</u>	<u>Explosion</u>	<u>Toxic By Products</u>	<u>Disposal Consid.</u>	<u>Storage Consid.</u>	<u>Safety Tests</u>
Pb/PbO ₂	X	X	X	X		X	
Zn/Alk/MnO ₂	X		X				
Ni/Cd	X	X	X	X			
Li/SO ₂	X	X	X	X	X	X	X
Li/SOCl ₂	X	X	X	X	X	X	X
Li/CF	X	X		X	X	X	X
Li/MnO ₂	X		X	X	X	X	
Zn/AgO	X	X	X	X	X		
Li/MoS ₂			X	X	X	X	

BATTERY RECHARGE MATRIX

	<u>Rechargeable</u>	<u>Discharge to Completion</u>	<u>Special Considerations</u>
Pb/PbO ₂	X		
Ni/Cd	X	X	
Zn/AgO	X	X	X ₁
Li/MoS ₂	X		X ₂

1. Only certain types can be recharged
2. Charging current may be limited.

SAFETY TESTS

Type of Battery	High Rate Discharge	Wet Stand	Short Circuit	Heat Tape	Reverse Charging	Environmental Testing
Pb/PbO ₂	X					X
Zn/Alk/MnO ₂						X
Li/SO ₂	X	X	X	X ₁	X	X
Li/SOCl ₂	X	X	X	X ₁	X	X
Li/CF	X	X	X	X ₁	X	X
Li/MnO ₂	X	X	X	X ₁	X	X
Zn/AgO	X					X
Li/MoS ₂	X	X	X	X	X	X

1. May be required.

OPERATIONAL CONSIDERATIONS

Type of Battery	O.C. Volts /Cell	High Temp.	Low Temp.	Vibr.	Energy Density	Power Density
Pb/PbO ₂	2.0	60°C	-40°C		30Wh/kg	High
Zn/Alk/MnO ₂		55	-20		38	Mod.
Ni/Cd	1.25	45	-20		20	Mod./High
Li/SO ₂	3.1	70	-55	C	280	High
Li/SOCl ₂	3.6	70	-40	C	300	Mod./High
Li/CF	3.1	55	-20		240	Mod.
Li/MoS ₂		50	-30		54	Mod.
Li/MnO ₂	3.5	55	-20		200	Mod.
Zn/AgO	1.6	55	0 ₁		130	Mod.

1. Requires heater.
2. C-concern

OPERATIONAL CONSIDERATIONS

<u>Type of Battery</u>	<u>Preheat Req.</u>	<u>Self Discharge</u>	<u>Voltage Delay</u>
Pb/PbO ₂	X ₁	X ₂	No
Zn/Alk/MnO ₂	X		Low ₃
Ni/Cd	X		No
Li/SO ₂			Mod. ₃
Li/SOCl ₂			High ₃
Li/CF			Low ₃
Li/MoS ₂			
Li/MnO ₂			Low ₃
Zn/AgO	X		Low

GENERAL NOTE: There is some degradation at low temperatures.

1. Below -30°C battery must be warmed.
2. Limited self discharge
3. Depends upon storage temperature.

LEGEND

Pb/PbO ₂	Lead Acid
Zn/Alk./MnO ₂	Alkaline
Ni/Cd	Nickel/Cadmium
Li/SO ₂	Lithium/Sulfur Dioxide
Li/SOCl ₂	Lithium/Thionyl Chloride
Li/CF	Lithium/Carbon Monofluoride
Li/MoS ₂	Lithium/Molybdenum Disulfide
Li/MnO ₂	Lithium/Manganese Dioxide
Zn/AgO	Zinc/Silver Oxide

Primary battery: A battery not intended to be recharged and is disposed of in controlled conditions when the battery has delivered all its electrical energy.

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Reserve battery: A battery which may be stored in an inactive state and made ready for use by adding electrolyte.